Coil Driven Alarm Design Considerations

INTRODUCTION

Normally, watch circuits, such as the ICM7220A, will drive a piezoelectric ceramic transducer at 3V pp directly, with an audio output of sufficient volume for wristwatch applications, providing the transducer is designed to have a resonant frequency of about 4 kHz when circumferentially edge mounted. There may be times, however, when greater output volume is desired, and this can be achieved by the addition of three components — a transistor, an inductor, and a resistor. (See Figure 1).

This circuit uses an NPN transistor, although certain devices require use of a PNP instead. (Figure 2). Table 1 shows the circuit which should be used with currently available Intersil devices.

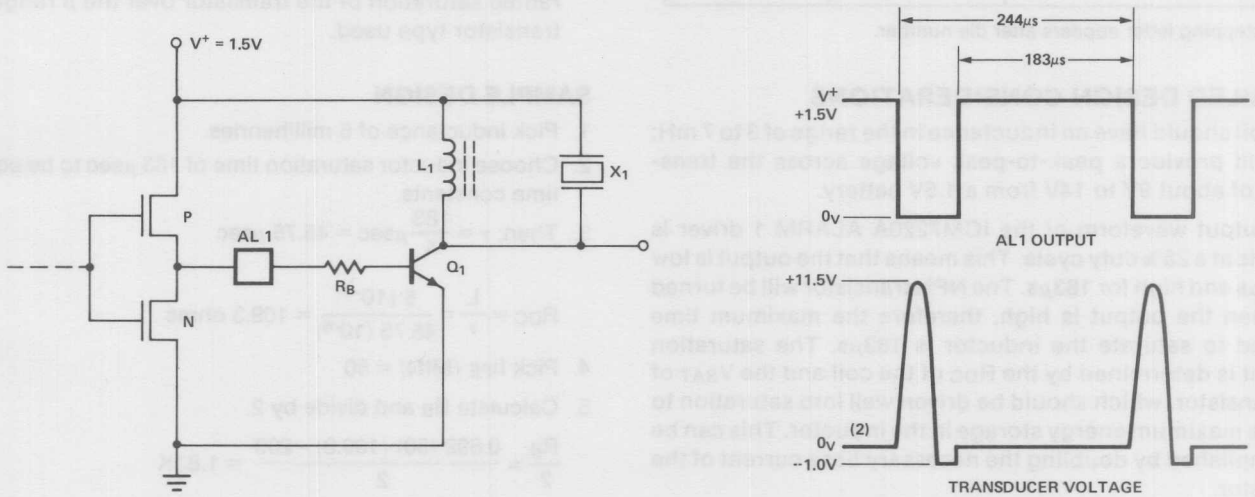

Figure 1. Use of an NPN Transistor and Associated Waveforms

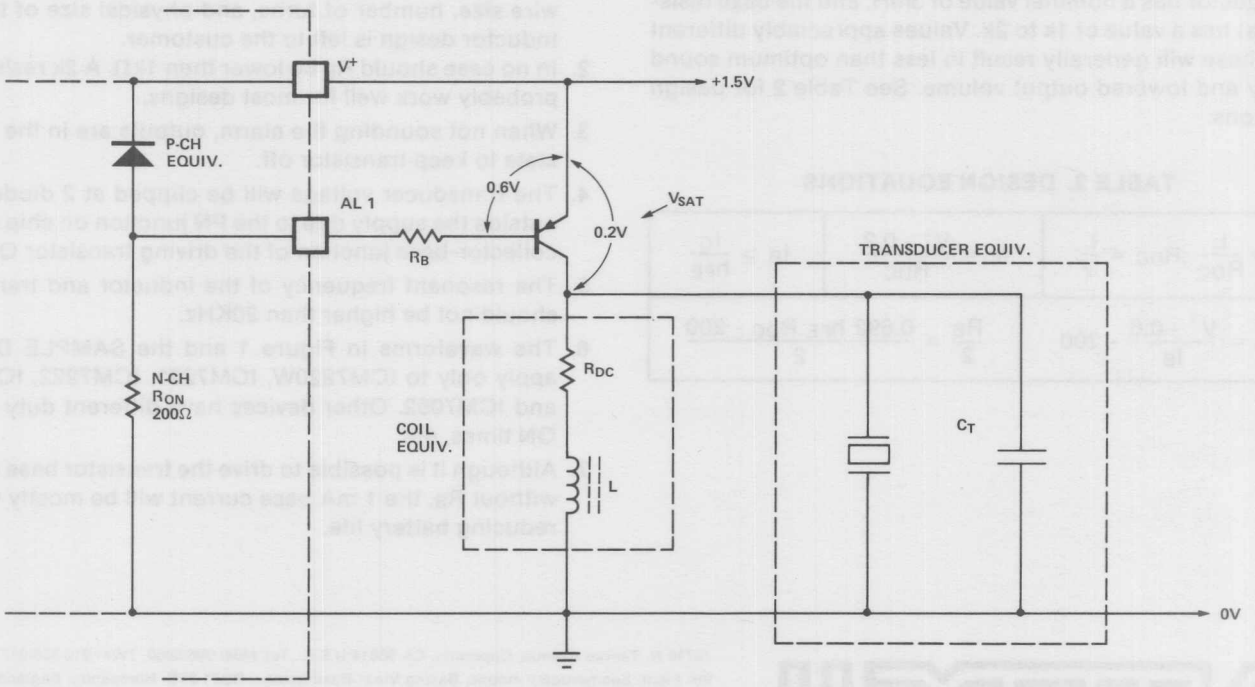

Figure 2. Equivalent Circuit Using PNP Transistor and Showing Non-Ideal Component Equivalents

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TABLE 1

Product	Die Stepping*	Circuit Figure Number
ICM7220A, MA	W	1
ICM7220FA, MFA	W	1
ICM7221	Z	2
ICM7222	Z, Y	2
ICM7222	W	1
ICM7223	all	1
ICM7052	all	2
ICM7049	all	2
ICM7050	all	2
ICM1115	all	2

*Die stepping letter appears after die number.

DETAILED DESIGN CONSIDERATIONS

The coil should have an inductance in the range of 3 to 7 mH; this will provide a peak-to-peak voltage across the transducer of about 9V to 14V from a 1.5V battery.

The output waveform of the ICM7220A ALARM 1 driver is 4096 Hz at a 25% duty cycle. This means that the output is low for 61μs and high for 183μs. The NPN transistor will be turned on when the output is high, therefore the maximum time allowed to saturate the inductor is 183μs. The saturation current is determined by the R_{DC} of the coil and the V_{SAT} of the transistor, which should be driven well into saturation to ensure maximum energy storage in the inductor. This can be accomplished by doubling the necessary base current of the transistor.

$$I_{B(MAX)} < 1\ mA,\ R_{B(MIN)} = 1k$$

It is recommended that the transistor $h_{FE}(\beta)$ be 50 or greater, the inductor has a nominal value of 5mH, and the base resistor (R_B) has a value of 1k to 2k. Values appreciably different from these will generally result in less than optimum sound quality and lowered output volume. See Table 2 for design equations.

TABLE 2. DESIGN EQUATIONS

$\tau = \frac{L}{R_{DC}}$; $R_{DC} = \frac{L}{\tau}$	$I_C = \frac{V^+ - 0.2}{R_{DC}}$	$I_B \geq \frac{I_C}{h_{FE}}$
$R_B = \frac{V^+ - 0.6}{I_B} - 200$	$\frac{R_B}{2} = \frac{0.692\ h_{FE}\ R_{DC} - 200}{2}$	

DESIGN STEPS

When designing a coil driven alarm circuit, several things must be taken into consideration. They are:

1. The DC resistance of the coil (R_{DC}). See note 1.
2. The transistor β (h_{FE})
3. The L/R time constant of the inductor.
4. The base resistance (R_B) needed to guarantee saturation of the transistor. See note 2.

The following steps should be used:

1. Select inductance.
2. Choose the time constant.
3. Calculate the coil resistance.
4. Choose a transistor with a minimum β (h_{FE}).
5. Calculate R_B and reduce calculated value by 50% to guarantee saturation of the transistor over the β range of the transistor type used.

SAMPLE DESIGN

1. Pick inductance of 5 millihenries.
2. Choose inductor saturation time of 183 μsec to be equal to 4 time constants.
3. Then: $\tau = \frac{183}{4}\ \mu sec = 45.75\ \mu sec$

$$R_{DC} = \frac{L}{\tau} = \frac{5\ (10^{-3})}{45.75\ (10^{-6})} = 109.3\ ohms$$

4. Pick h_{FE} (MIN) = 50
5. Calculate R_B and divide by 2.

$$\frac{R_B}{2} = \frac{0.692\ (50)\ (109.3) - 200}{2} = 1.80K$$

NOTES:

1. R_{DC} is used to design the inductor and will determine the wire size, number of turns, and physical size of the coil. Inductor design is left to the customer.
2. In no case should R_B be lower then 1kΩ. A 2k resistor will probably work well for most designs.
3. When not sounding the alarm, outputs are in the correct state to keep transistor off.
4. The transducer voltage will be clipped at 2 diode drops outside the supply due to the PN junction on chip and the collector-base junction of the driving transistor Q1.
5. The resonant frequency of the inductor and transducer should not be higher than 20KHz.
6. The waveforms in Figure 1 and the SAMPLE DESIGN apply only to ICM7220W, ICM7221, ICM7222, ICM7223, and ICM7052. Other devices have different duty cycles, ON times, etc.
7. Although it is possible to drive the transistor base directly without R_B, the 1 mA base current will be mostly wasted, reducing battery life.

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